



LRFD

Section 3.77

New: April 2005

[CLICK HERE TO Index](#)

3.77.1 General

- 1.1 Material Properties

3.77.2 Design

- 2.1 Limit States and Factors
- 2.2 Loads
- 2.3 General Design Assumptions
- 2.4 End Bent Analysis
- 2.5 Beam Reinforcement Special Cases

3.77.3 Dimensions

- 3.1 Front Sheet
- 3.2 Wing Brace
- 3.3 Prestressed Girder End Bent
- 3.4 Steel Girder or Beam End Bent
- 3.5 Wing & Detached Wing Walls

3.77.4 Reinforcement

- 4.1 Wide Flange & Plate Girders
- 4.2 Prestressed Girders
- 4.3 Wide Flange, Plate Girders & Prestressed Girders

3.77.5 Details

- 5.1 Reinforcing Holes
- 5.2 Vertical Drains

3.77.1 General

1.1 Material Properties

Concrete

Class B Concrete (Substructure)

$$f'_c = 3.0 \text{ ksi}$$

$$n = 10$$

Class B-1 Concrete (Substructure) may also be used in special cases (See Project Manager). The following equations shall apply to both concrete classes:

LRFD 5.4.2.4

Concrete modulus of elasticity, $E_c = 33000 K_1 w_c^{1.5} \sqrt{f'_c}$

Where:

w_c = unit weight of non-reinforced concrete = 0.145 kcf

K_1 = correction factor for source of aggregate = 1.0.

LRFD 5.4.2.6

Modulus of rupture: For minimum reinforcement, $f_r = 0.37 \sqrt{f'_c}$

For all other calculations, $f_r = 0.24 \sqrt{f'_c}$

$\sqrt{f'_c}$ is in units of ksi

Reinforcing Steel

Minimum yield strength,

$$f_y = 60.0 \text{ ksi}$$

LRFD 5.4.3.2

Steel modulus of elasticity,

$$E_s = 29000 \text{ ksi}$$

Deep Foundations

See LRFD DG Sec. 3.80 or Sec. 3.81 for pile or drilled shaft information. Also check the Design Layout if a foundation capacity is indicated.

Shallow Foundations

See the Design Layout for the allowable footing pressure. If omitted, refer to LRFD DG Sec. 8.1.2.19.

3.77.2 Design

2.1 Limit States and Factors

In general, each component shall satisfy the following equation:

LRFD 1.3.2.1

$$Q = \sum \eta_i \gamma_i Q_i \leq \phi R_n = R_r$$

Where:

Q = Total factored force effect

Q_i = Force effect

η_i = Load modifier

γ_i = Load factor

ϕ = Resistance factor

R_n = Nominal resistance

R_r = Factored resistance

LRFD 5.5

Limit States

The following limit states shall be considered for abutment design:

STRENGTH – I

STRENGTH – III

STRENGTH – IV

STRENGTH – V

SERVICE – I

FATIGUE

EXTREME EVENT – II

See LRFD Table 3.4.1-1 and LRFD 3.4.2 for Loads and Load Factors applied at each given limit state.

Resistance factors

LRFD 5.5.4.2

STRENGTH limit states, see LRFD 5.5.4.2 & 6.5.4.2

LRFD 1.3.2.1

For all other limit states, $\phi = 1.00$

LRFD 1.3.2.1

Load Modifiers

For loads where a maximum value of load factor is appropriate:

$$\eta = (\eta_I \eta_R \eta_D) \geq 0.95$$

For loads where a minimum value of load factor is appropriate:

$$\eta = 1 / (\eta_I \eta_R \eta_D) \leq 1.0$$

Where:

LRFD 1.3.3

η_D = Factor relating to ductility

LRFD 1.3.4

η_R = Factor relating to redundancy

LRFD 1.3.5

η_I = Factor relating to operational importance

Table 3.77.2.1.1 Load modifiers

	All Limit States
Ductility, η_D	1.0
Redundancy, η_R	1.0
Operational importance, η_I	1.0
$\eta = (\eta_I \eta_R \eta_D)$	1.0
$\eta = 1 / (\eta_I \eta_R \eta_D)$	1.0

2.2 Loads

See LRFD DG Sec. 1.2 Loads for distribution and magnitudes of loads to be applied for abutment design.

Dead Loads

Loads from stringers, girders, etc. shall be applied as concentrated loads applied at the centerline of bearing. Loads from concrete slab spans shall be applied as uniformly distributed loads.

Live Loads

Loads from stringers, girders, etc. shall be applied as concentrated loads applied at the centerline of bearing. Dynamic load allowance (impact) should be included for the design of the beam. No dynamic load allowance should be included for foundation design.

For wings with detached wing walls, no portion of the bridge live load shall be distributed to the detached wall. The detached wing wall shall be designed as a retaining wall as specified in LRFD DG Sec. 3.62. The weight of the safety barrier curb on top of the wall shall be included in the dead load.

Collision

LRFD 3.6.5.2

Collision shall be designed if abutments are located within a distance of 30.0 feet to the edge of roadway, or within a distance of 50.0 feet to the centerline of a railway track and conditions do not qualify for exemptions given in LRFD DG Sec. 1.2.2.5-2. If designed for, the collision force shall be a static force of 400 kips assumed to act in any direction in a horizontal plane, at a distance of 4.0 feet above ground.

2.3 General Design Assumptions

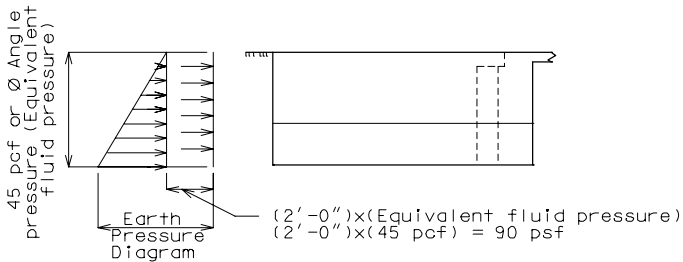
Beam

The beam shall be assumed continuous over supports at centerline of piles.

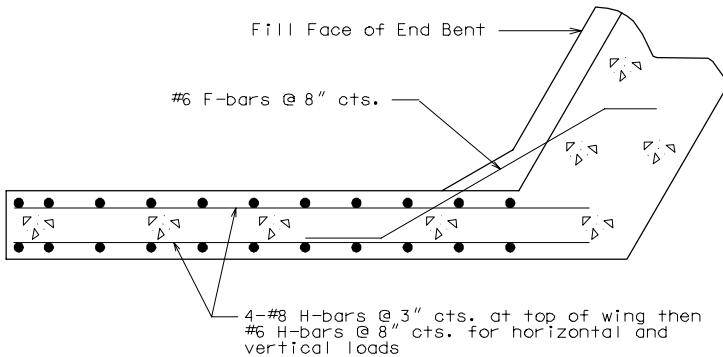
One half of the dead load of the approach slab shall be included in the beam design.

Wing

The standard horizontal reinforcement shown below was designed for soil pressure, EH, live load surcharge, LS and a railing collision force, CT for Extreme Limit State II Load Combination.



The minimum steel placed horizontally in wings shall be as shown in the figure below.



PART SECTION THRU BEAM

2.4 End Bent Analysis

The following steps shall be used to design integral end bents.

Step 1 – Obtain loads from superstructure

The live load reactions (LL), dead load of structural components (DC), and dead load of future wearing surface (DW) will be needed to design the end bents. Strength I Load Combination will be used to design the reinforcement and Service I Load Combination will be used to design the pile capacity.

Step 2 – Design bearing pads or girder chairs

From the loads obtained in Step 1, design the bearing pads or girder chairs according to LRFD DG Sec. 3.31.

Step 3 – Find beam cap width

The standard beam cap width will be 3'-0". However, if the bearing pad size required exceeds the allowable edge distance, the beam cap width may be widened. The bearing pads shall be centered over the centerline of pile location, which is 15" away from the stream or crossing face of the cap.

Step 4 – Design longitudinal steel in beam cap

If the centerline of bearing is 12" or less on the centerline of piles, use 4 - #6 bars at the top and bottom of the beam cap. Otherwise, the ultimate moment used for designing the longitudinal steel shall be approximated by the following equation and as shown in LRFD DG Fig. 3.77.2.4.1. The loads shall be factored according to the Strength I Load Combination.

$$M_u = 0.2 R_u L + 0.13 W L^2$$

Where:

R_u = maximum interior girder reaction of factored superstructure loads, kips.

L = pile spacing, ft.

W = factored substructure loads equally distributed across the beam, k/ft.

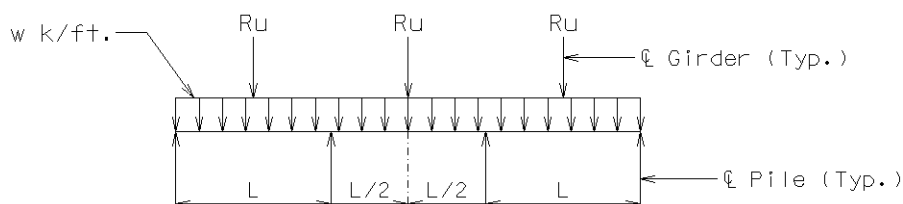


Figure 3.77.2.4.1 Basic Assumption for Beam Analysis

A minimum of 4 - #6 Bars shall be used for the longitudinal steel in the beam cap. If more steel is required, increase bar size and keep the number of bars to 4. For example, use 4 - #7 bars instead of 5 - #6 bars.

Step 5 – Design for number and size of piles

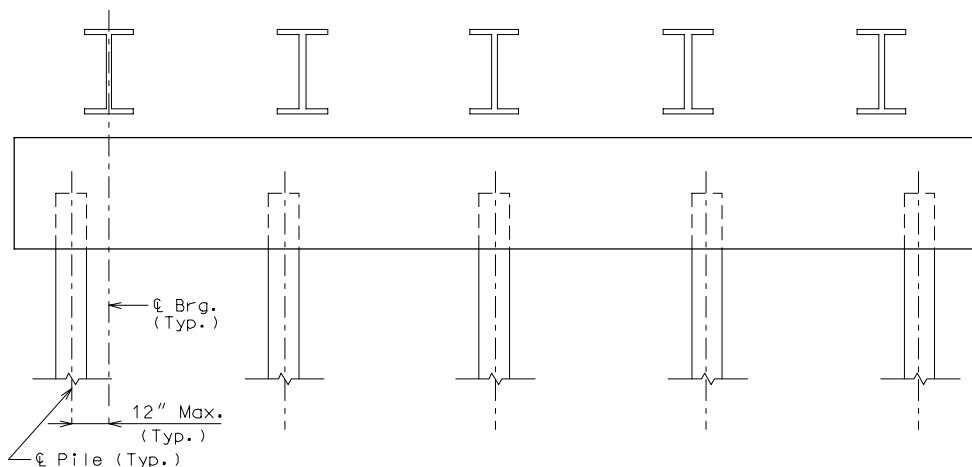
Loads from the superstructure and substructure for designing piles shall be factored according to the Service I Load Combination and shall be equally distributed to all piles.

Step 6 – Find hammer energy needed for piles

2.5 BEAM REINFORCEMENT SPECIAL CASES

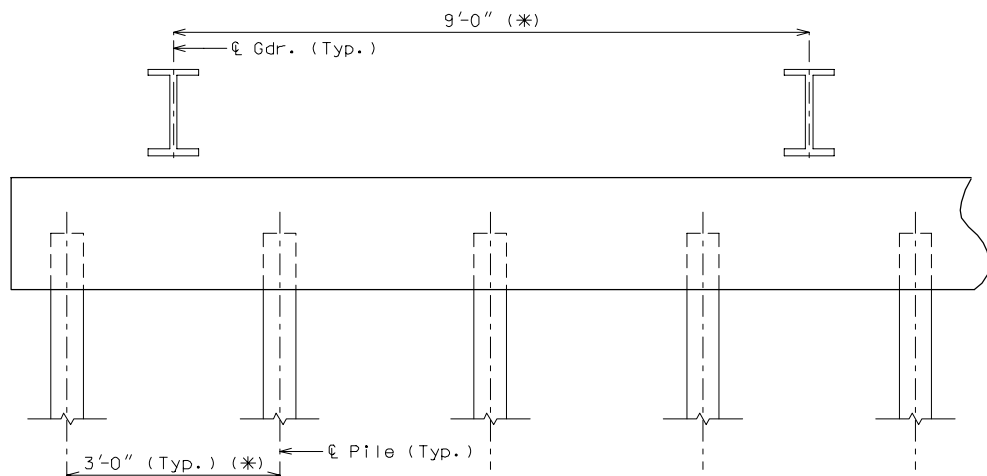
SPECIAL CASE I

If ℓ bearing is 12" or less on either side of ℓ piles, for all piles (as shown below), use 4-#6 top and bottom and #4 at 12" cts. (stirrups), regardless of pile size.



SPECIAL CASE II

When beam reinforcement is to be designed assuming piles to take equal force, design for negative moment in the beam over the interior piles.

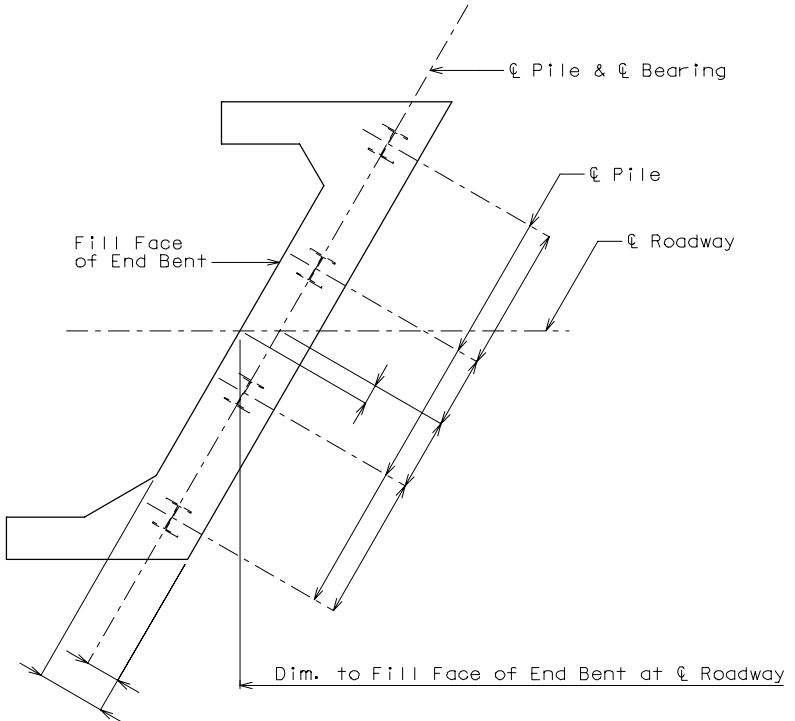


(*) Dimensions shown are for illustration purposes only.

3.1 Front Sheet

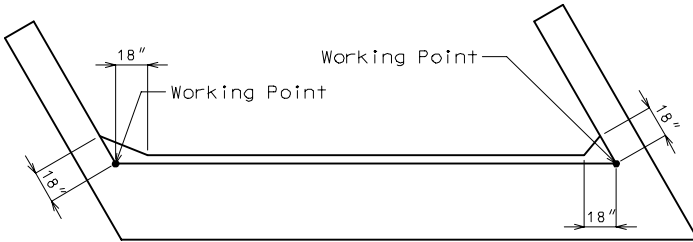
Note: The following are details and dimensions for the Plan view on the Front Sheets.

Details for unsymmetrical roadways will require dimensions tying Centerline Lane to Centerline Structure.

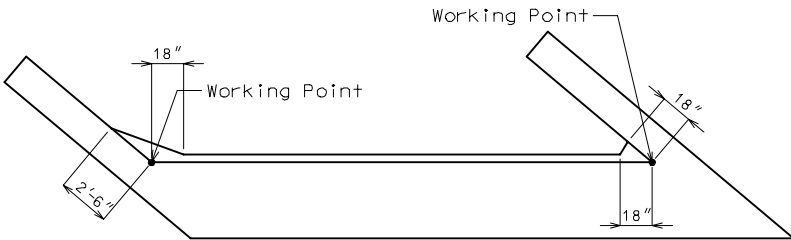


3.2 Wing Brace

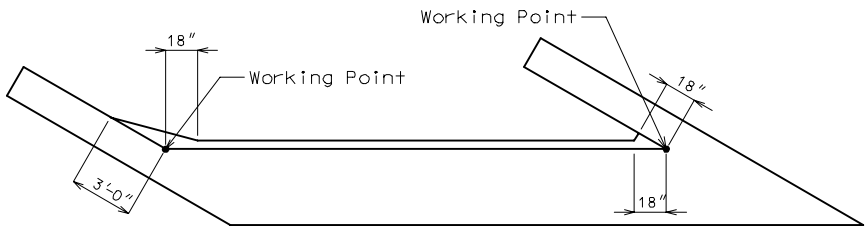
The wing brace dimensions will only vary on the wing with obtuse angle. Wing brace dimensions shown are minimum dimensions. The wing brace with the acute angle will always be 18" minimum.



SKEWS THRU 0° TO 45°



SKEWS THRU 45°00'01" TO 55°

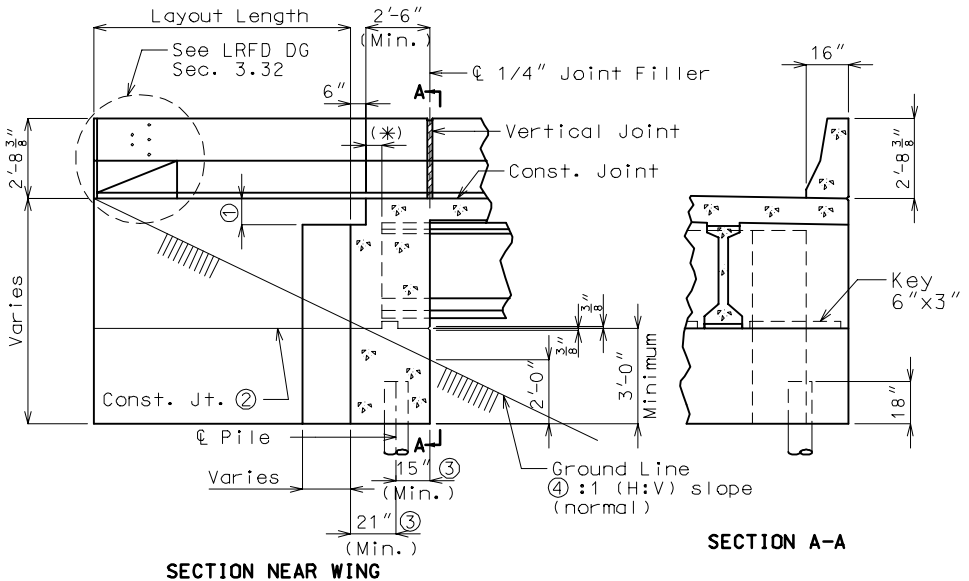


SKEWS THRU 55°00'01" AND OVER

Note:

Left advance shown, right advance similar.

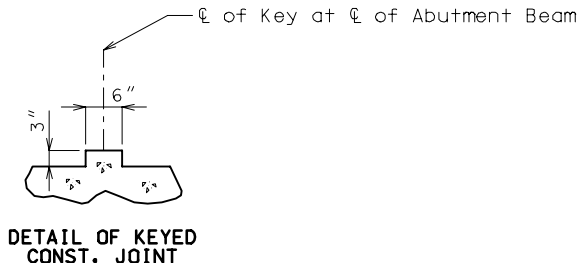
3.3 Prestressed Girder End Bent



Note:

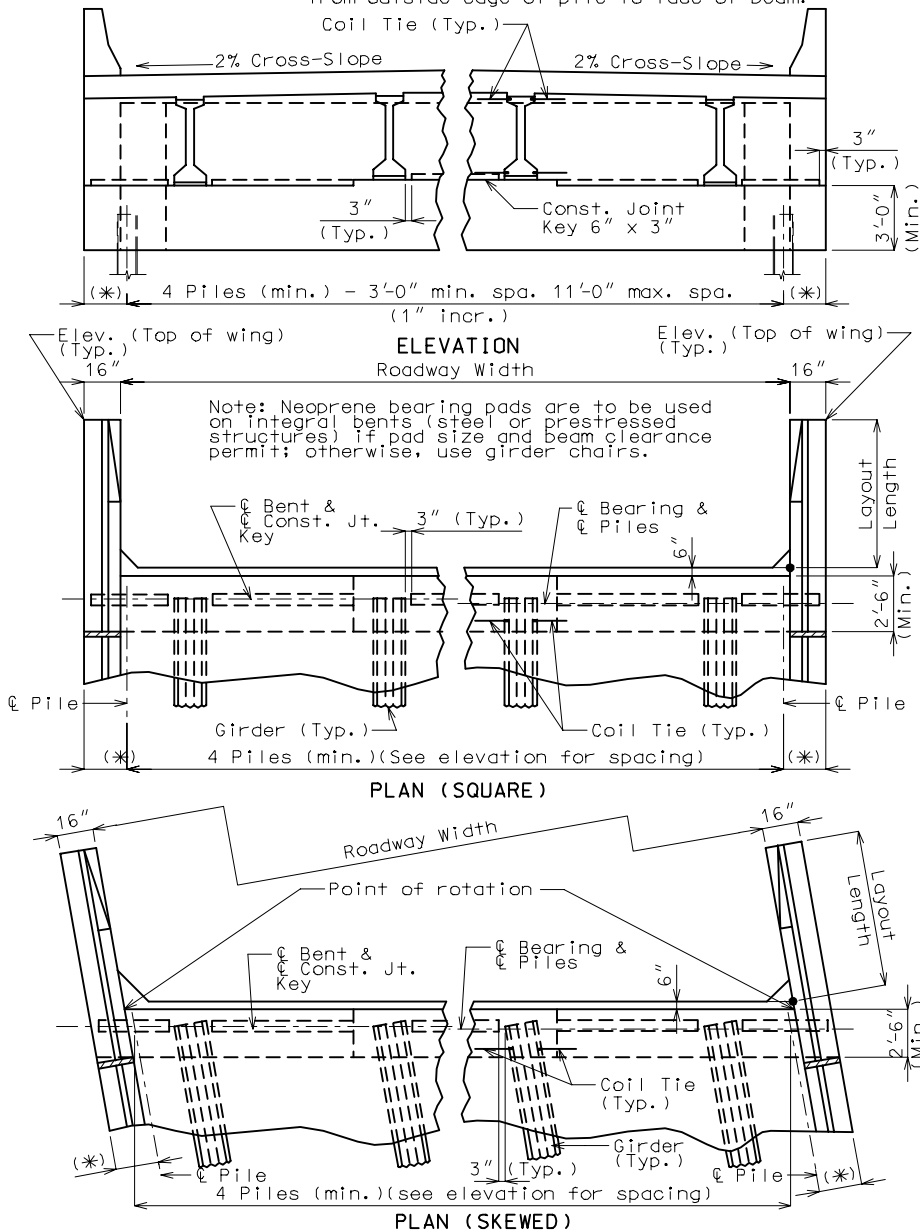
- ① 12" Minimum at gutter line top of concrete.
- ② All concrete in the end bent above top of beam and below top of slab shall be class B-2, see proper notes in LRFD DG Sec. 4.0 Office Notes.
- ③ Provide a minimum of 9" Cl. from outside edge of pile to face of beam.
- ④ See Design Layout for maximum slope of spill fill.

(*) Keep 1 1/2" Min. clear cover for a #6 bar reinforcement between approach notch and girder. Increase abutment beam width (1" increments) to get the 1 1/2" clear cover if necessary.



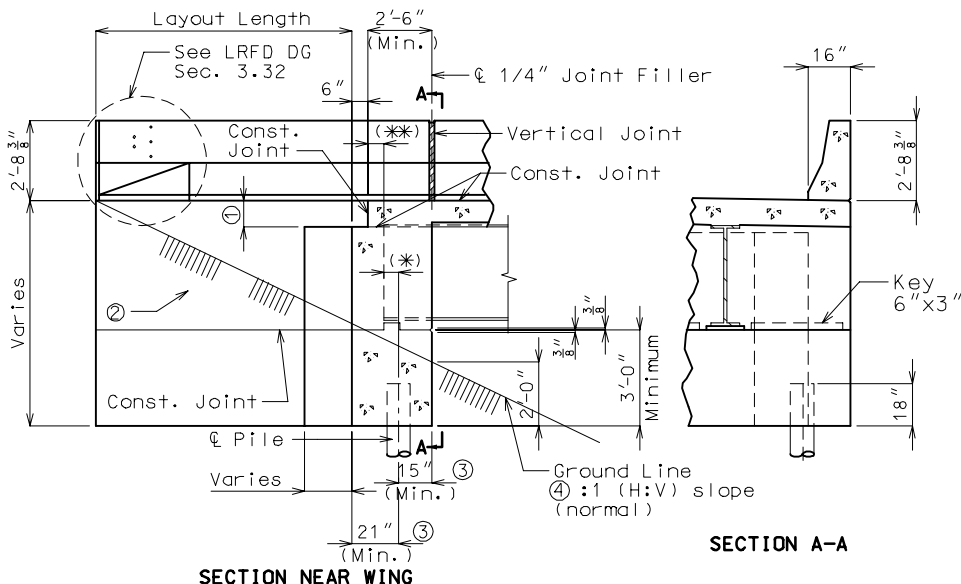
Prestressed Girder End Bent

* 18" Min., 2'-0" Max., provide a minimum of 9" cl. from outside edge of pile to face of beam.

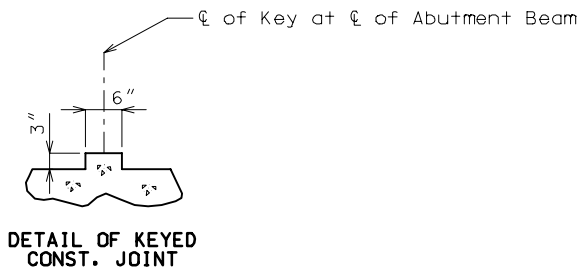


See LRFD DG Sec. 3.77.3.2 for wing brace details.

3.4 Steel Girder or Beam End Bent



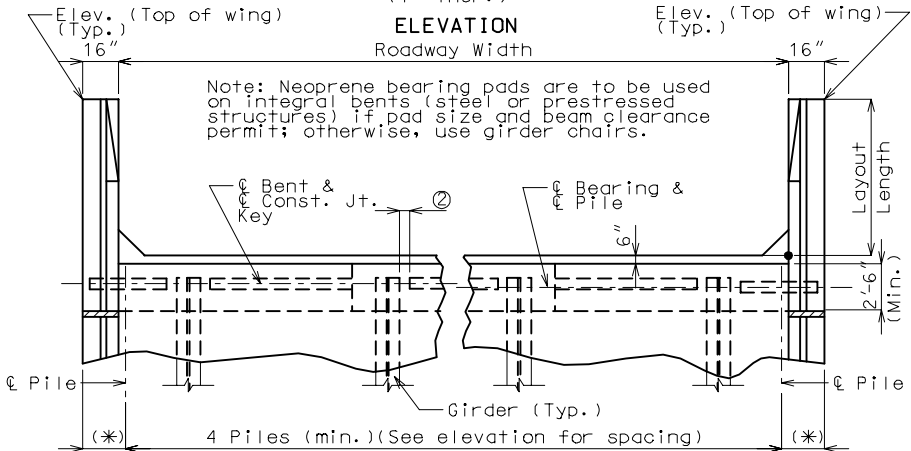
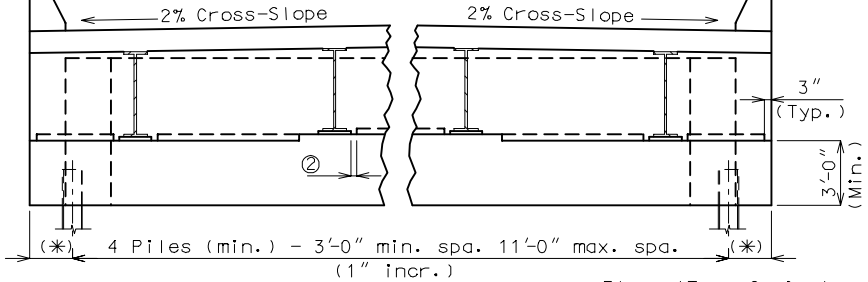
- ① 12" Minimum at gutter line top of concrete.
 - ② All concrete in the end bent above top of beam and below top of slab shall be class B-2, see proper notes in LRFD DG Sec. 4.0 Office Notes.
 - ③ Provide a minimum of 9" Cl. from outside edge of pile to face of beam.
 - ④ See Design Layout for maximum slope of spill fill.
- (*) Use 3" Min. when girder chairs are used and use 1" past the end of the bearing pad when bearing pads are used.
- (**) Keep 1 1/2" Min. clear cover for a #6 bar reinf. between approach notch and girder. Increase abutment beam width (1" increments) to get the 1 1/2" clear cover if necessary.



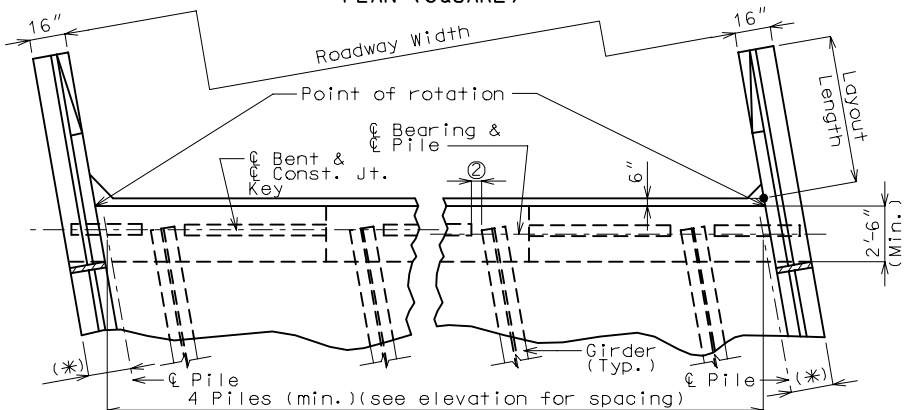
Steel Girder or Beam End Bent

② 3" cl. between sole plate and keyed const. joint (Typ.)

* 18" Min. 2'-0" Max., provide a minimum of 9" cl. from outside edge of pile to face of beam.



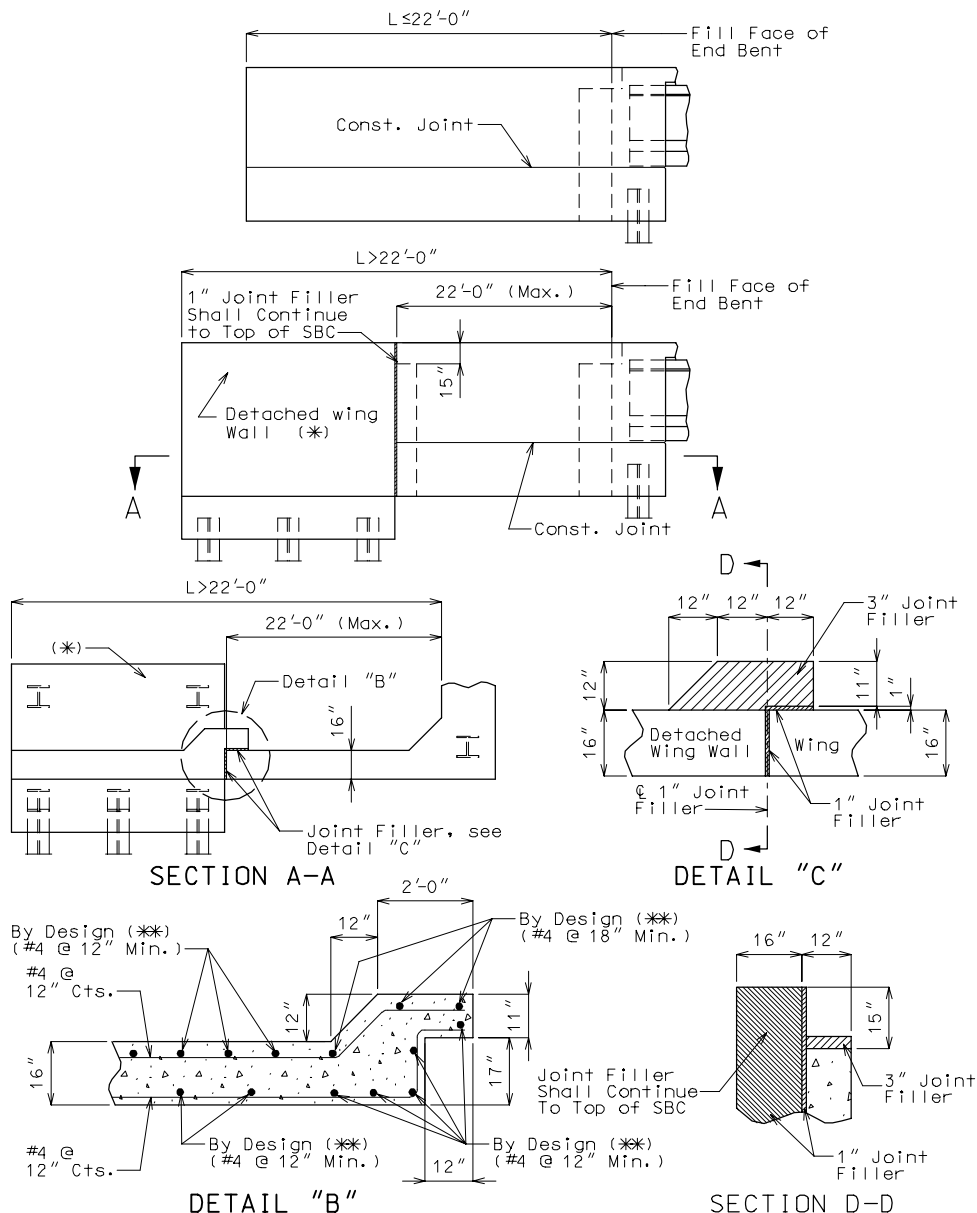
PLAN (SQUARE)



PLAN (SKEWED)

See LRFD DG Sec. 3.77.3.2 for wing brace details.

3.5 Wings and Detached Wing Walls

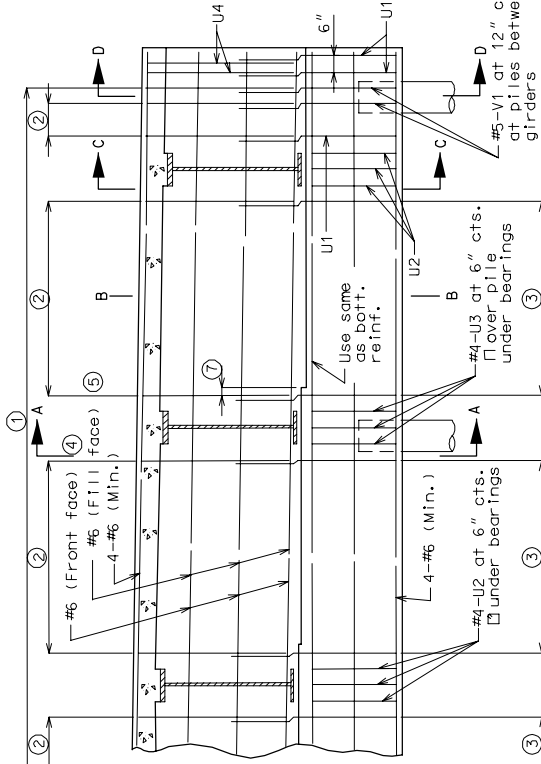


(*) Detached wing wall shown is for illustration purpose only. Design detached wing wall as a retaining wall, see LRFD DG Sec. 3.62.

(**) See Retaining Wall Design.

4.1 SQUARE WING/SQUARE APPROACH SLAB NOTCH
WIDE FLANGES & PLATE GIRDERS

Reinforcement



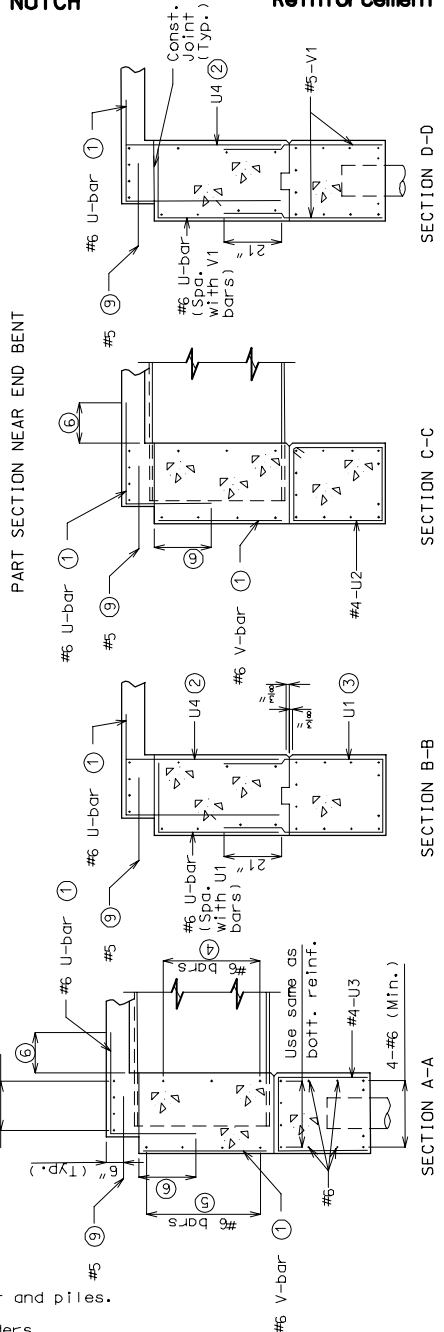
Place U1, U2, U3, U4, and V1 bars parallel to \perp Roadway.

- ① #6 U-bar Γ (horiz. leg placed parallel to \perp Roadway) and #6 V-bar or U-bar @ 9" cts. min. (Between barrier curbs).
- ② #5-U4 at 12" cts. Γ - spaced with U1 and V1 bars.
- ③ U1 at 12" cts. Γ - spaced between piles and girders. #5 bars, except special cases listed in LRFD DG Sec. 3.77.2.5.
- ④ See tables in LRFD DG Sec. 3.77.5.1 for 1-1/16" \varnothing hole spacing for #6 reinf. bars.
- ⑤ Same number of bars as 1-1/16" \varnothing holes in stringer or girder.
- ⑥ By design - development length (top bars) min., see LRFD DG Sec. 2.4.11.
- ⑦ Stirrups shall clear step by 1-1/2" min., if not lengthen step or skew step.
- ⑧ #5 bars, 2'-6" long, spaced at 12" cts. along \perp bent. Bars placed parallel to \perp Rdwy.

Place note on plans if Girder Chairs are used:
Shift the reinforcing steel to keep 1-1/2" clearance of the angles of the girder chairs.

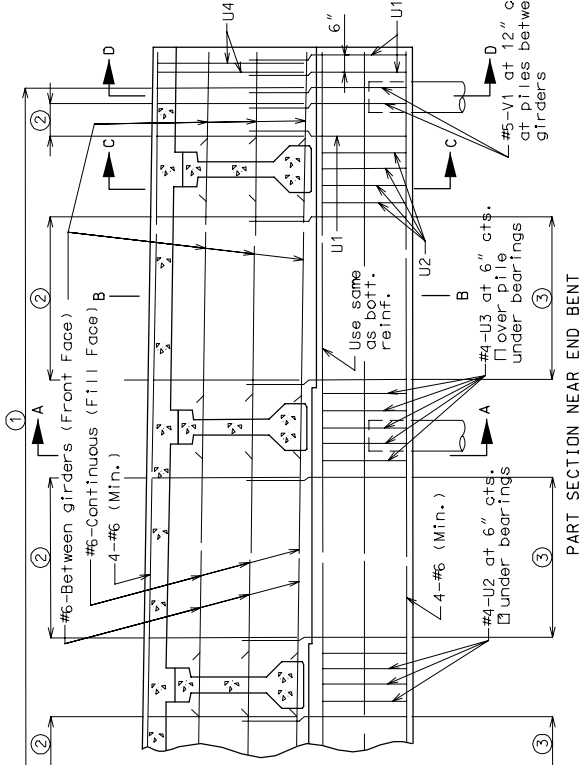
Keep 1-1/2" clearance between shear reinforcement and piles.

(Replace U1 bars with U3 bars at piles under girders and with V1 bars at piles between girders.)



4.2 SQUARE WING/SQUARE APPROACH SLAB NOTCH PRESTRESSED GIRDERS

Reinforcement

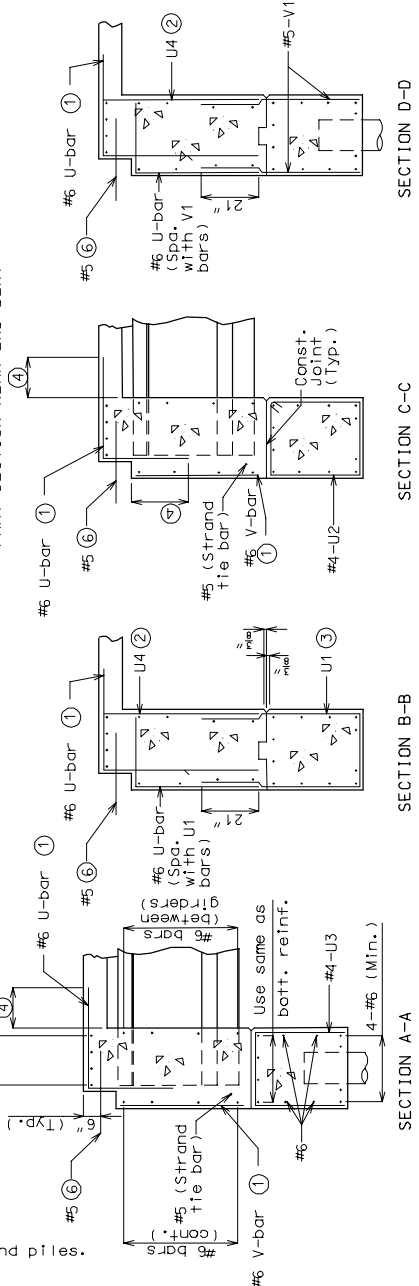


Place U1, U2, U3, U4, and V1 bars parallel to ϵ Roadway.

- ① #6 U-bar Γ (horiz. leg placed parallel to ϵ Roadway) and #6 V-bar or U-bar @ 9" cts. min. (Between barrier curbs).
- ② #5-U4 at 12" cts. Γ - spaced with U1 and V1 bars.
- ③ U1 at 12" cts. U - spaced between piles and girders.
(Replace U1 bars with U3 bars at piles under girders and with V1 bars at piles between girders). #5 bars, except special cases listed in LRFD DG Sec. 3.77.2.5.
- ④ By design - development length (top bars) min., see LRFD DG Sec. 2.4.11.
- ⑥ #5 bars, 2'-6" long, spaced at 12" cts. along ϵ bent. Bars placed parallel to ϵ Rdwy.

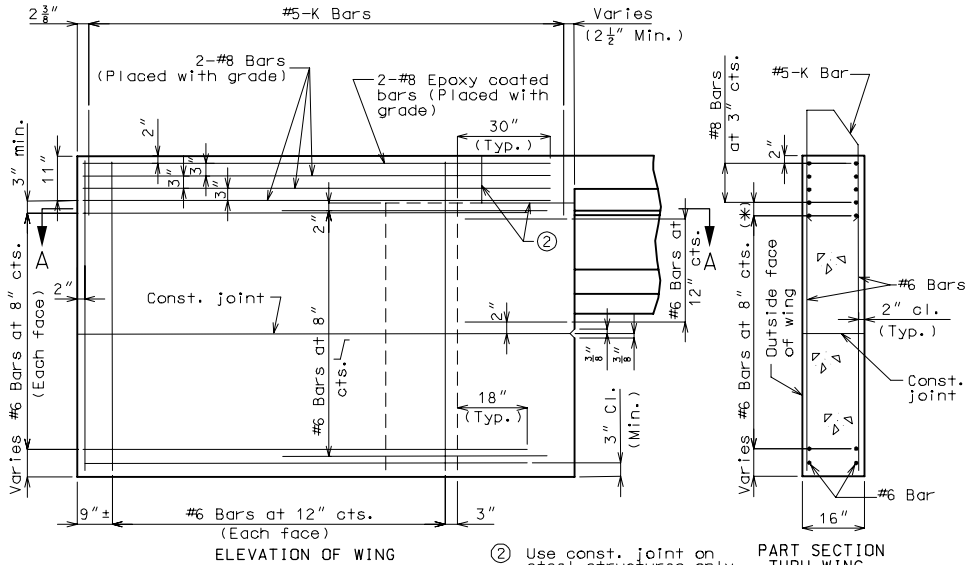
Place note on plans if girder chairs are used:
Shift the reinforcing steel to keep 1-1/2" clearance of the angles of the girder chairs.

Keep 1-1/2" clearance between shear reinforcement and piles.

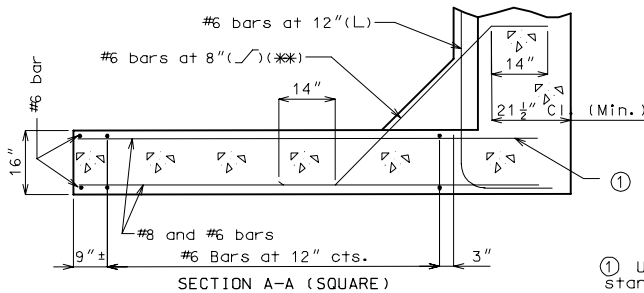


4.3 SQUARE WING/SQUARE APPROACH SLAB NOTCH WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS

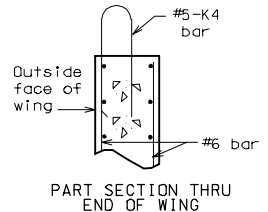
Reinforcement



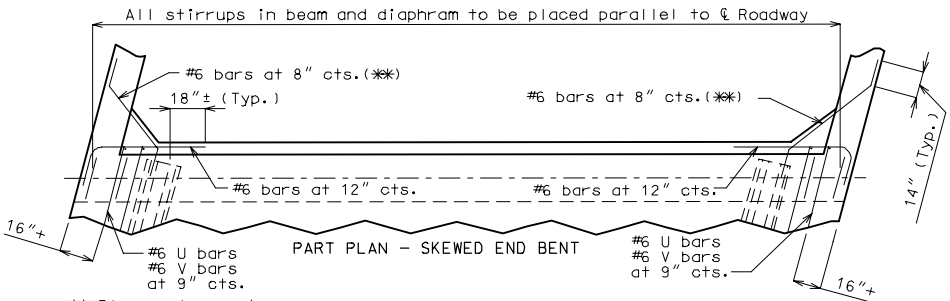
(*) Keep a min. of 3" ctr. to ctr. spacing between #6 bars placed horizontally and #8 bars placed with grade.



(K bars not shown for clarity)



① Use 90° standard hook in SPC B, C, & D.



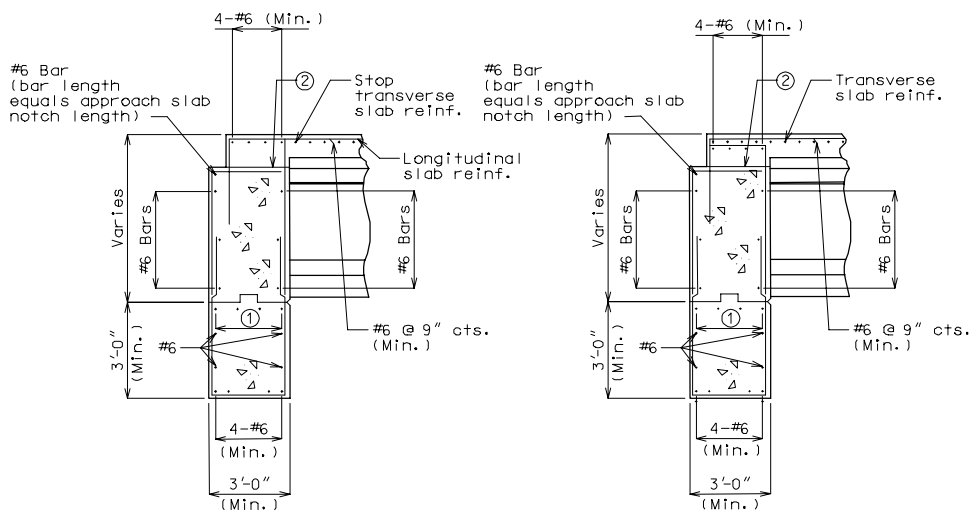
* Place note on plans
Bend --- F bars in field to clear girder.

Note: See LRFD DG Sec. 3.32 for barrier curb details and spacing of K bars.
Prestressed I-Girders shown in details. Steel Girders similar.

SQUARE WING/SQUARE APPROACH SLAB NOTCH

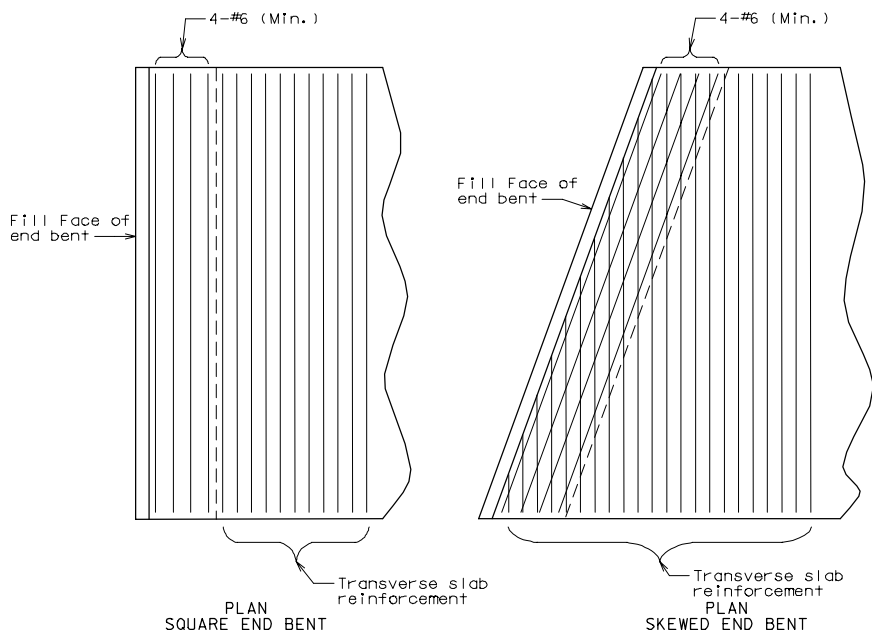
Reinforcement

WIDE FLANGES, PLATE GIRDERS & PRESTRESSED GIRDERS



SECTION THRU
SQUARE END BENT

SECTION THRU
SKEWED END BENT



PLAN
SQUARE END BENT

PLAN
SKEWED END BENT

Note: Sections shown above are between girders and piles.

Prestressed I girders are shown in the sections above; Steel girders are similar.

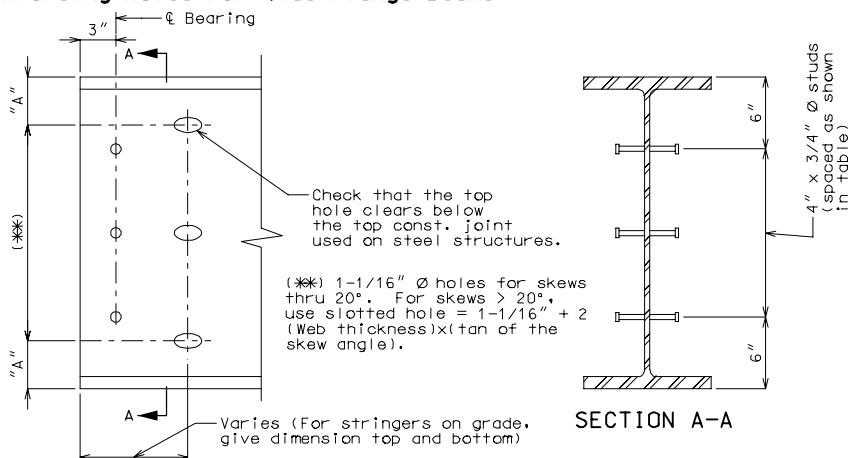
- ① Use same as bottom reinforcement.
- ② Use construction joint on steel structures only.

3.77.5 Details

Details

5.1 Reinforcing Holes

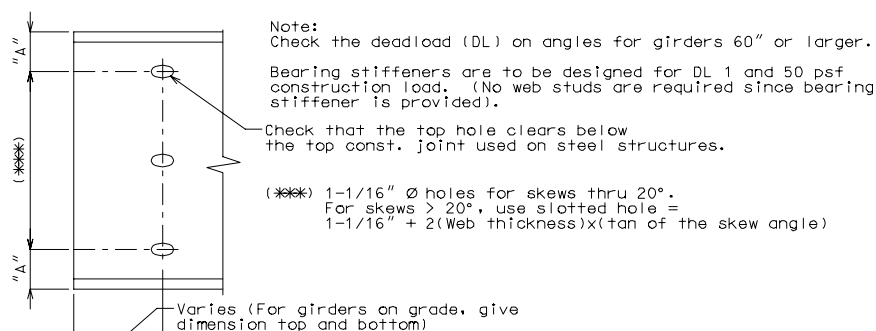
Reinforcing Holes For Wide Flange Beams



Section At End Of Stringer

WF BEAM DEPTH	STUD SPACING	"A"	REINFORCING HOLE SPACING
21"	2 spa. @ 4-1/2"	4"	2 equal spaces
24"	2 spa. @ 6"	4"	2 equal spaces
27"	2 spa. @ 7-1/2"	4-1/2"	2 equal spaces
30"	3 spa. @ 6"	4-1/2"	3 equal spaces
33"	3 spa. @ 7"	4-1/2"	3 equal spaces
36"	4 spa. @ 6"	4-1/2"	3 equal spaces

Reinforcing Holes For Plate Girders



Section At End Of Girder

PL GDR DEPTH	"A"	REINFORCING HOLE SPACING
39"	3-1/2"	4 equal spaces
42"	3-1/2"	5 equal spaces
48"	4"	5 equal spaces
54"	4-1/2"	6 equal spaces
60"	4"	8 equal spaces

5.2 Vertical Drains

Vertical Drains Without Intermediate Wings

